

Final Report
Relativistic Astrophysics in Black Hole and Low-
Mass Neutron Star X-ray Binaries
NAG-5-7927

During the five-year period, our study of "Relativistic Astrophysics in Black Hole and Low-Mass Neutron Star X-ray Binaries" has been focused on the following aspects: observations, data analysis, Monte-Carlo simulations, numerical calculations, and theoretical modeling. Most of the results of our study have been published in refereed journals (18) and conference presentations (26) as listed below:

Refereed Publications

1. Title: **Evidence for Doppler-shifted Iron Emission Lines in Black Hole Candidate 4U 1630-47**
Authors: Cui, Wei; Chen, Wan; **Zhang, Shuang Nan**
Journal: The Astrophysical Journal, Volume 529, Issue 2, pp. 952-960.
Publication Date: 02/2000
Origin: UCP
ApJ Keywords: STARS: BINARIES: GENERAL, LINE: PROFILES, STARS: INDIVIDUAL (4U 1630-47), X-RAYS: STARS
Abstract Copyright: (c) 2000: The American Astronomical Society
Bibliographic Code: 2000ApJ...529..952C

Abstract

We report the first detection of a pair of correlated emission lines in the X-ray spectrum of black hole candidate 4U 1630-47 during its 1996 outburst, based on Rossi X-Ray Timing Explorer (RXTE) observations of the source. At the peak plateau of the outburst, the emission lines are detected, centered mostly at ~ 5.7 and ~ 7.7 keV, respectively, while the line energies exhibit random variability $\sim 5\%$. Interestingly, the lines move in a concerted manner to keep their separation roughly constant. The lines also vary greatly in strength, but with the lower energy line always much stronger than the higher energy one. The measured equivalent width ranges from ~ 50 to ~ 270 eV for the former, and from insignificant detection to ~ 140 eV for the latter; the two are reasonably correlated.

The correlation between the lines implies a causal connection; perhaps they share a common origin. Both lines may arise from a single K α line of highly ionized iron that is Doppler shifted either in a Keplerian accretion disk or in a bipolar outflow or even both. In both scenarios, a change in the line energy might simply reflect a change in the ionization state of line-emitting matter. We discuss the implication of the results and also raise some questions about such interpretations.

2. Title: **Three-Layered Atmospheric Structure in Accretion
Disks Around Stellar-Mass Black Holes**
Authors: **Zhang, S. N.**; Cui, Wei; Chen, Wan; Yao, Yangsen;
Zhang, Xiaoling; Sun, Xuejun; Wu, Xue-Bing;
Xu, Haiguang
Journal: Science, Volume 287, Issue 5456, pp. 1239-1241
(2000).
Publication Date: 02/2000
Category: ASTRONOMY
Origin: SCIENCE
Abstract Copyright: (c) 2000: Science
Bibliographic Code: 2000Sci...287.1239Z

Abstract

Modeling of the x-ray spectra of the Galactic superluminal jet sources GRS 1915+105 and GRO J1655-40 reveals a three-layered atmospheric structure in the inner region of their accretion disks. Above the cold and optically thick disk with a temperature of 0.2 to 0.5 kiloelectron volts, there is a warm layer with a temperature of 1.0 to 1.5 kiloelectron volts and an optical depth around 10. Sometimes there is also a much hotter, optically thin corona above the warm layer, with a temperature of 100 kiloelectron volts or higher and an optical depth around unity. The structural similarity between the accretion disks and the solar atmosphere suggests that similar physical processes may be operating in these different systems.

3. Title: **Hard X-Ray Detection of the High-Redshift Quasar 4C
71.07**
Authors: Malizia, A.; Bassani, L.; Dean, A. J.;
McCollough, M.; Stephen, J. B.; **Zhang, S. N.**;
Paciesas, W. S.
Journal: The Astrophysical Journal, Volume 531, Issue 2, pp.
642-646.
Publication Date: 03/2000
Origin: UCP
ApJ Keywords: GALAXIES: ACTIVE, GAMMA RAYS: OBSERVATIONS,
QUASARS:
INDIVIDUAL (4C 71.07), X-RAYS: GALAXIES
Abstract Copyright: (c) 2000: The American Astronomical Society
Bibliographic Code: 2000ApJ...531..642M

Abstract

BATSE/OSSE observations of the high-redshift quasar 4C 71.07 indicate that this is the brightest and farthest active galactic nucleus so far detected above 20 keV. BATSE Earth occultation data have been used to search for emissions from 4C 71.07 from nearly 3 yr of observation. The mean source flux over the whole period in the BATSE energy range 20-100 keV is $(1.32 \pm 0.11) \times 10^{-10}$ ergs cm⁻² s⁻¹, corresponding to a luminosity of 2×10^{48} ergs s⁻¹. The BATSE light curve over the 3 yr of observations shows several flarelike events, one of which (in 1996 January) is

associated with an optical flare ($R=16.1$) but with a delay of 55 days. The OSSE/BATSE spectral analysis indicates that the source is characterized by a flat power spectrum ($\Gamma \sim 1.1-1.3$) when in a low state; this spectral form is consistent within errors with the ASCA and ROSAT spectra. This means that the power law observed from 0.1 to 10 keV

extends up to at least 1 MeV, but steepens soon after to meet EGRET high-energy data. BATSE data taken around the 1996 January flare suggest

that the spectrum could be steeper when the source is in a bright state.

The νF_ν representation of the source is typical of a low-frequency-peaked/gamma-ray-dominated blazar, with the synchrotron peak in the millimeter-far-infrared band and the Compton peak in the MeV

band. The BATSE and OSSE spectral data seem to favor a model in which the high-energy flux is due to the sum of the synchrotron self-Compton and the external Compton contributions; this is also supported by the variability behavior of the source.

4. Title: Phase Lag and Coherence Function of X-Ray Emission from Black Hole Candidate XTE J1550-564

Authors: Cui, Wei; Zhang, Shuang Nan; Chen, Wan

Journal: The Astrophysical Journal, Volume 531, Issue 1, pp. L45-L48.

Publication Date: 03/2000

Origin: UCP

ApJ Keywords: BLACK HOLE PHYSICS, STARS: INDIVIDUAL:

ALPHANUMERIC:

XTE J1550-564, STARS: OSCILLATIONS, X-RAYS: STARS

Abstract Copyright: (c) 2000: The American Astronomical Society

Bibliographic Code: 2000ApJ...531L..45C

Abstract

We report the results from measuring the phase lag and coherence function of X-ray emission from black hole candidate XTE J1550-564. These temporal X-ray properties have been recognized to be increasingly important in providing important diagnostics of the dynamics of accretion flows around black holes. For XTE J1550-564, we found significant hard lag-the X-ray variability in high-energy bands lags behind that in low-energy bands-associated both with broadband variability and quasi-periodic oscillation (QPO). However, the situation

is more complicated for the QPO: while hard lag was measured for the first harmonic of the signal, the fundamental component showed significant soft lag. Such behavior is remarkably similar to what was observed of microquasar GRS 1915+105. The phase lag evolved during the initial rising phase of the 1998 outburst. The magnitude of both the soft and hard lags of the QPO increases with X-ray flux, while the Fourier spectrum of the broadband lag varies significantly in shape. The

coherence function is relatively high and roughly constant at low frequencies and begins to drop almost right after the first harmonic of

the QPO. It is near unity at the beginning and decreases rapidly during the rising phase. Also observed is that the more widely separated the two energy bands are, the less the coherence function between the two. It is interesting that the coherence function increases significantly at the frequencies of the QPO and its harmonics. We discuss the implications of the results on the models proposed for black hole candidates.

5. Title: **The Timing Evolution of 4U 1630-47 during Its 1998 Outburst**
Authors: Dieters, S. W.; Belloni, T.; Kuulkers, E.; Woods, P.;
Cui, W.; **Zhang, S. N.**; Chen, W.; van der Klis, M.;
van Paradijs, J.; Swank, J.; Lewin, W. H. G.;
Kouveliotou, C.
Journal: The Astrophysical Journal, Volume 538, Issue 1, pp. 307-314.
Publication Date: 07/2000
Origin: UCP
ApJ Keywords: Accretion, Accretion Disks, Stars: Binaries: Close, stars: individual (4U 1630-47), X-Rays: Stars
Abstract Copyright: (c) 2000: The American Astronomical Society
Bibliographic Code: 2000ApJ...538..307D

Abstract

We report on the evolution of the timing of 4U 1630-47 during its 1998 outburst using data obtained with the Rossi X-ray Timing Explorer (RXTE). The count rate and position in hardness intensity, color-color diagrams, and simple spectral fits are used to track the concurrent spectral changes. The source showed seven distinct types of timing behavior, most of which show differences with the canonical black hole spectral/timing states. In marked contrast to previous outbursts, we find quasi-periodic oscillation (QPO) signals during nearly all stages of the outburst with frequencies between 0.06 and 14 Hz and a remarkable variety of other characteristics. In particular, we find large (up to 23% rms) amplitude QPOs on the early rise. Later, slow 0.1 Hz semiregular short (~5 s), 9%-16% deep dips dominate the light curve. At this time there are two QPOs, one stable near 13.5 Hz and the other whose frequency drops from the 6-8 Hz range to ~4.5 Hz during the dips. BeppoSAX observations during the very late declining phase show 4U 1630-47 in a low state.

6. Title: **ASCA Observation of the Superluminal Jet Source GRO J1655-40 in the 1997 Outburst**
Authors: Yamaoka, Kazutaka; Ueda, Yoshihiro; Inoue, Hajime; Nagase, Fumiaki; Ebisawa, Ken; Kotani, Taro; Tanaka, Yasuo; **Zhang, Shang Nan**;
Journal: Publications of the Astronomical Society of Japan, vol.53, no. 2, p. 179-188.

Publication Date: 04/2001
Origin: PASJ
Keywords: ACCRETION, ACCRETION DISKS, BINARIES: CLOSE, STARS:
INDIVIDUAL (GRO J1655-40), X-RAYS: STARS
Abstract Copyright: (c) 2001: Astronomical Society of Japan
Bibliographic Code: 2001PASJ...53..179Y

Abstract

We report on the results of an ASCA observation of the Galactic jet source GRO J1655-40 performed from 1997 February 25 to February 28 covering a full orbital period (2.62 d). The averaged 2-10 keV flux was about 1.1 Crab. An absorption line feature centered at 6.8 keV was detected both in the GIS and SIS spectra. We interpret this as a blend of two resonance-absorption $K\alpha$ lines from H-like and He-like iron ions. We can consistently explain both the ASCA spectra and the simultaneous RXTE/PCA spectrum by a combination of K-absorption lines and K-absorption edges of iron ions. The fact that the absorption line is stably present over the whole orbital phase implies that the distribution of the highly ionized plasma is not affected by the companion star, which is consistent with its presence around the black hole. A curve of growth analysis shows that the plasma contains velocity dispersion along the line-of-sight larger than 300 km s^{-1} attributed to bulk motions. It is probably a part of a geometrically thick accretion flow in turbulent motions with velocities of $500\text{--}1600 \text{ km s}^{-1}$ at an estimated radius of $\sim 10^{10} \text{ cm}$.

7. Title: Evolution of Iron $K\alpha$ Line Emission in the Black Hole Candidate GX 339-4

Authors: Feng, Y. X.; Zhang, S. N.; Sun, X.; Durouchoux, Ph.;
Chen, Wan; Cui, Wei
Journal: The Astrophysical Journal, Volume 553, Issue 1, pp.
394-398.
Publication Date: 05/2001
Origin: UCP
ApJ Keywords: Stars: Binaries: Close, Black Hole Physics, stars:
individual (GX 339-4), X-Rays: Stars
Abstract Copyright: (c) 2001: The American Astronomical Society
Bibliographic Code: 2001ApJ...553..394F

Abstract

GX 339-4 was regularly monitored with the Rossi X-Ray Timing Explorer during a period (in 1999) when its X-ray flux decreased significantly (from 4.2×10^{-10} to $7.6 \times 10^{-12} \text{ ergs cm}^{-2} \text{ s}^{-1}$ in the 3-20 keV band), as the source settled into the "off state." Our spectral analysis revealed the presence of a prominent iron $K\alpha$ line in the observed spectrum of the source for all observations. The line shows an interesting evolution: it is centered at ~ 6.4 keV when the measured flux is above $5 \times 10^{-11} \text{ ergs cm}^{-2} \text{ s}^{-1}$ but is shifted to ~ 6.7 keV at lower fluxes. The equivalent width of the line appears to increase significantly toward lower fluxes, although it is likely to be sensitive to calibration uncertainties. While the

fluorescent emission of neutral or mildly ionized iron atoms in the accretion disk can perhaps account for the 6.4 keV line, as is often invoked for black hole candidates, it seems difficult to understand the 6.7 keV line with this mechanism because the disk should be less ionized at lower fluxes (unless its density changes drastically). On the other hand, the 6.7 keV line might be due to a recombination cascade of hydrogen- or helium-like iron ions in an optically thin, highly ionized plasma. We discuss the results in the context of proposed accretion models.

8. Title: **The Burst and Transient Source Experiment Earth Occultation Technique**
Authors: Harmon, B. A.; Fishman, G. J.; Wilson, C. A.; Paciesas, W. S.; Zhang, S. N.; Finger, M. H.; Koshut, T. M.; McCollough, M. L.; Robinson, C. R.; Rubin, B. C.
Journal: The Astrophysical Journal Supplement Series, Volume 138, Issue 1, pp. 149-183.
Publication Date: 01/2002
Origin: UCP
ApJ Keywords: Gamma Rays: Observations, Instrumentation: Detectors, Methods: Data Analysis, Occultations, Surveys, X-Rays: Stars
Abstract Copyright: (c) 2002: The American Astronomical Society
Bibliographic Code: 2002ApJS..138..149H

Abstract

An Earth orbiting detector sensitive to gamma-ray photons will see steplike occultation features in its count rate when a gamma-ray point source crosses the Earth's limb. This is due to the change in atmospheric attenuation of the gamma rays along the line of sight. In an uncollimated detector, these occultation features can be used to locate and monitor astrophysical sources provided their signals can be individually separated from the detector background. We show that the Earth occultation technique applied to the Burst and Transient Source Experiment (BATSE) on the Compton Gamma Ray Observatory (CGRO) is a viable and flexible all-sky monitor in the low-energy gamma-ray and hard X-ray energy range (20 keV-1 MeV). The method is an alternative to more sophisticated photon imaging devices for astronomy and can serve well as a cost-effective science capability for monitoring the high-energy sky. Here we describe the Earth occultation technique for locating new sources and for measuring source intensity and spectra without the use of complex background models. Examples of transform imaging, step searches, spectra, and light curves are presented. Systematic uncertainties due to source confusion, detector response, and contamination from rapid background fluctuations are discussed and analyzed for their effect on intensity measurements. A sky location-dependent average systematic error is derived as a function of Galactic coordinates. The sensitivity of the technique is derived as a function of incident photon energy and also as a function of angle

between the source and the normal to the detector entrance window. Occultations of the Crab Nebula by the Moon are used to calibrate Earth occultation flux measurements independent of possible atmospheric scattering effects.

9. Title: **A Chandra Spectroscopic Survey of Persistent Black Hole Candidates**
Authors: Cui, Wei; Feng, Y. X.; Zhang, S. N.; Bautz, M. W.; Garmire, G. P.; Schulz, N. S.
Journal: The Astrophysical Journal, Volume 576, Issue 1, pp. 357-365.
Publication Date: 09/2002
Origin: UCP
ApJ Keywords: Accretion, Accretion Disks, Black Hole Physics, X-Rays: Binaries, X-Rays: Individual: Alphanumeric: LMC X-1, X-Rays: Individual: Alphanumeric: LMC X-3, X-Rays: Individual: Alphanumeric: GRS 1758-258, X-Rays: Individual: Constellation Name: Cygnus X-1, X-Rays: Stars
Abstract Copyright: (c) 2002: The American Astronomical Society
Bibliographic Code: 2002ApJ...576..357C

Abstract

We present results from observations of persistent black hole candidates with the High-Energy Transmission Gratings on board the Chandra X-Ray Observatory. The sources include LMC X-1, LMC X-3, GRS 1758-258, and Cyg X-1. Along with the published results on 1E 1740.7-2942, we have completed a high-resolution spectroscopic survey of such systems. The observed X-ray spectra of LMC X-1 and LMC X-3 show no prominent discrete features, while absorption edges (Mg K and Si K) are detected in the spectrum of GRS 1758-258. The edges are likely to be of interstellar origin. In most cases, the X-ray continuum can be described well by models that are often adopted in low-resolution studies of black hole candidates: a multitemperature disk spectrum plus a Comptonization component. However, the relative contribution of the two components varies greatly among different sources. For instance, only the disk component is present for LMC X-1 and GRS 1758-258, while the Comptonized component is required for other sources. We discuss general issues related to obtaining disk parameters from modeling X-ray continuum.

10. Title: **Low-Frequency Coherence Break in the Soft X-Ray State of GRS 1915+105**
Authors: Ji, Jian Feng; Zhang, Shuang Nan; Qu, Jin Lu; Li, Ti Pei
Journal: The Astrophysical Journal, Volume 584, Issue 1, pp. L23-L26. (<A

[href="http://www.journals.uchicago.edu/ApJ">ApJ Homepage](http://www.journals.uchicago.edu/ApJ)

Publication Date: 02/2003

Origin: UCP

ApJ Keywords: Accretion, Accretion Disks, Stars: Individual:
Alphanumeric: GRS 1915+105, X-Rays: Binaries

Abstract Copyright: (c) 2003: The American Astronomical Society

Bibliographic Code: 2003ApJ...584L..23J

Abstract

We present results from the analysis of X-ray power density spectra and coherence when GRS 1915+105 is in soft states. We use three data sets that belong to μ , ϕ , and δ classes as found in the work of

Belloni et al. We find that the power density spectra appear to be complex, with several features between 0.01 and 10 Hz. The coherence deviates from unity above a characteristic frequency. We discuss our results from different models. The corona size in the sphere-disk model implied by this break frequency is on the order of

$10^{4.2} GM/c^{0.5}$, which is unphysical. Our results are more consistent with the prediction of the model of a planar corona sustained by magnetic flares, in which the characteristic frequency is associated with the longest timescale of an individual flare, which is about 8 s.

11. Title: **Simplified formulae system for resonant inverse Compton scattering of a fast electron in an intense magnetic field**

Authors: You, J. H.; Chen, W. P.; Zhang, S. N.; Chen, L.;
Liu, D. B.; Chou, C. K.

Journal: Monthly Notice of the Royal Astronomical Society,
Volume 340, Issue 2, pp. 687-693.

Publication Date: 04/2003

Origin: MNRAS

MNRAS Keywords: radiation mechanisms: non-thermal, scattering,
 γ -rays: theory

Abstract Copyright: (c) 2003 RAS

Bibliographic Code: 2003MNRAS.340..687Y

Abstract

We present simple analytical formulae for the emission spectrum and total power of a special kind of resonant inverse Compton scattering (RICS) of a relativistic electron in an intense magnetic field. In contrast with the available formulae system, we obtain a markedly simplified one based on the semiclassical quantum theory, which is more understandable for people who are unfamiliar with quantum electrodynamics. We show that the RICS process, under an appropriate 'accommodation condition' derived in this paper, is predominantly much more efficient than the coexistent ordinary inverse Compton scattering, and produces highly beamed high-frequency radiation with moderately good

monochromaticity. Our formulae are simple to use - thus offering a lucid

physical intuition for the theory - and may find wide applications in hard X-ray and γ -ray astrophysics.

12. Title: **BeppoSAX observations of two unclassified LMXBs:
X1543-624 and X1556-605**
Authors: Farinelli, R.; Frontera, F.; Masetti, N.; Amati, L.;
Guidorzi, C.; Orlandini, M.; Palazzi, E.;
Parmar, A. N.; Stella, L.; Van der Klis, M.;
Zhang, S. N.
Journal: Astronomy and Astrophysics, v.402, p.1021-1032
(2003)
Publication Date: 05/2003
Origin: A&A
A&A Keywords: stars: individual: X1543-624, X1556-605, X-rays:
general, X-rays: stars, stars: neutron, accretion,
accretion disks
Abstract Copyright: (c) 2003: Astronomy & Astrophysics
Bibliographic Code: 2003A&A...402.1021F

Abstract

Observations of two unclassified Low Mass X-ray Binaries, X1543-624 and X1556-605, are presented. In the 2-10 keV band the first of the two sources is a factor of two stronger than the other. Both sources do not show X-ray bursts, dips or eclipses in their X-ray light curves. We find that both spectra are described by a two-component model consisting of emission from a cool accretion disk plus a Comptonized blackbody with $kT_{\text{bb}} \sim 1.5$ keV in a low opacity plasma. The spectrum of X1543-624 hardens from the first to the second observation, when the source slowly moves from right to left in the colour-colour diagram. The spectrum of X1556-605 can also be described by a model consisting of a blackbody plus an unsaturated Comptonization with electron energy $kT_{\text{e}} \sim 4$ keV. In the first observation, X1543-624 shows evidence of a Fe K emission line at 6.4 keV. Moreover, in both observations, the source spectrum exhibits an emission feature around 0.7 keV, which is interpreted as due to the superposition of the K edge absorption features of O and Ne elements with uncommon relative abundances with respect to the solar one ($O/O_{\text{sun}} \sim 0.3$, $Ne/Ne_{\text{sun}} \sim 2.5$). In the spectrum of X1556-605 no emission lines are observed. We discuss these results and their implications for the source classification and the accretion geometry of the compact object.

13. Title: **Improving the spatial resolution of XMM-Newton EPIC images by direct demodulation technique}**
Authors: Feng, Hua; Chen, Yong; **Zhang, S. N.**; Lu, F. J.;
Li, T. P.
Journal: Astronomy and Astrophysics, v.402, p.1151-1155

(2003)
Publication Date: 05/2003
Origin: A&A
A&A Keywords: techniques: high angular resolution, techniques:
image processing
Abstract Copyright: (c) 2003: Astronomy & Astrophysics
Bibliographic Code: 2003A&A...402.1151F

Abstract

We have applied the direct demodulation technique to XMM-Newton EPIC images to achieve a higher spatial resolution; the restored images are compared with Chandra images. With the improved images we can extract spectra of fine structures in XMM-Newton data.

14. Title: An Accretion Model for the Growth of the Central Black Hole Associated with Ionization Instability in Quasars
Authors: Lu, Y.; Cheng, K. S.; Zhang, S. N.
Journal: The Astrophysical Journal, Volume 590, Issue 1, pp. 52-57.
Publication Date: 06/2003
Origin: UCP
ApJ Keywords: Accretion, Accretion Disks, Black Hole Physics, Galaxies: Active, Galaxies: Bulges, Galaxies: Nuclei, Galaxies: Quasars: General
Abstract Copyright: (c) 2003: The American Astronomical Society
Bibliographic Code: 2003ApJ...590...52L

Abstract

A possible accretion model associated with the ionization instability of quasar disks is proposed to address the growth of the central black hole (BH) harbored in the host galaxy. The evolution of quasars in cosmic time is assumed to change from a highly active state to a quiescent state triggered by the S-shaped ionization instability of the quasar accretion disk. For a given external mass transfer rate \dot{M}_{ext} supplied by the quasar host galaxy, ionization instability can modify the accretion rate in the disk and separate the accretion flows of the disk into three different phases, like an S-shape. We suggest that the bright quasars observed today are those quasars with disks in the upper branch of the S-shaped instability, and the faint or "dormant" quasars are simply these systems in the lower branch. The middle branch is the transition state, which is unstable. We assume the quasar disk evolves according to the advection-dominated inflow-outflow solution (ADIOS) configuration in the stable lower branch of the S-shaped instability, and the Eddington accretion rate is used to constrain the accretion rate in the highly active phase. The mass ratio between a BH and its host galactic bulge is a natural consequence of an ADIOS. Our model also demonstrates that a seed BH ($\sim 10^{-6} M_{\text{solar}}$) similar to those found in

spiral galaxies today is needed to produce a BH with a final mass of $\sim 2 \times 10^8 M_{\text{solar}}$.

15. Title: Thermal iron K α ; line emission from the X-ray binary GX 339-4

Authors: Xu, Y. D.; Zhang, S. N.; Zhang, X. L.; Liu, D. B.;
Chen, L.; Xu, H. G.; You, J. H.
Journal: New Astronomy, Volume 8, Issue 6, p. 575-580.
Publication Date: 08/2003
Origin: ELSEVIER
Abstract Copyright: (c) 2003 Elsevier B.V.
Bibliographic Code: 2003NewA....8..575X

Abstract

The accretion rate of the black hole candidate X-ray binary GX 339-4 in the 'off' state is low, and an advection dominated accretion flow (ADAF)

is present. Hydrogen-like and helium-like iron K α ; emission lines at 6.7 and 6.95 keV from hot plasma of ADAF can be produced by recombination-cascade processes with moderately high intensities, which are markedly distinguished from the fluorescent iron K α ; line at ~ 6.4 keV. We show that the observational features of GX 339-4 can be explained by the ADAF model, if the iron abundance is more than 10 times

the solar value, though the reason for such a high abundance is still unclear. We suggest that the increase of the accretion rate makes GX 339-4 change from off, low, intermediate, to high and very high states, and the line center of iron K α ; will therefore shift from ~ 6.83 to ~ 6.4 keV, i.e. to the fluorescent disc-line, since the disappearance of the ADAF due to its high accretion rate.

16. Title: A New Method to Resolve X-Ray Halos around Point Sources with Chandra Data and Its Application to Cygnus X-1

Authors: Yao, Yangsen; Zhang, Shuang Nan; Zhang, Xiaoling; Feng, Yuxin
Journal: The Astrophysical Journal, Volume 594, Issue 1, pp. L43-L46.
Publication Date: 09/2003
Origin: UCP
ApJ Keywords: ISM: Dust, Extinction, X-Rays: Binaries, X-Rays: Individual: Constellation Name: Cygnus X-1, X-Rays: ISM
Abstract Copyright: (c) 2003: The American Astronomical Society
Bibliographic Code: 2003ApJ...594L..43Y

Abstract

With excellent angular resolution, good energy resolution, and a broad energy band, the Chandra Advanced CCD Imaging Spectrometer (ACIS) is the best instrument for studying the X-ray halos around some Galactic X-ray

point sources caused by the dust scattering of X-rays in the interstellar medium. However, the direct images of bright sources obtained with the ACIS usually suffer from severe pileup. Making use of the fact that an isotropic image could be reconstructed from its projection into any direction, we can reconstruct the images of the X-ray halos from the data obtained with the High Energy Transition Grating Spectrometer (HETGS) and/or in continuous clocking (CC) mode. These data have no or less serious pileup and enable us to take full advantage of the excellent angular resolution of Chandra. With the reconstructed high-resolution images, we can probe the X-ray halos as close as 1" to their associated point sources. Applying this method to Cygnus X-1 observed with the Chandra HETGS in CC mode, we derived an energy-dependent radial halo flux distribution and concluded that in a circular region (2' in radius) centered at the point source: (1) relative to the total intensity, the fractional halo intensity is about 15% at ~1 keV and drops to about 5% at ~6 keV (2) about 50% of the halo photons are within the region of a radius less than 40" and (3) the spectrum of the point source is slightly distorted by the halo contamination.

17. Title: Probing the Inflow/Outflow and Accretion Disk of Cygnus X-1 in the High State with the Chandra High Energy Transmission Grating

Authors: Feng, Y. X.; Tennant, A. F.; Zhang, S. N.

Journal: The Astrophysical Journal, Volume 597, Issue 2, pp. 1017-1022.

Publication Date: 11/2003

Origin: UCP

ApJ Keywords: Accretion, Accretion Disks, Stars: Binaries: General, Black Hole Physics, Stars: Individual: Constellation Name: Cygnus X-1, X-Rays: Binaries

Abstract Copyright: (c) 2003: The American Astronomical Society

Bibliographic Code: 2003ApJ...597.1017F

Abstract

Cygnus X-1 was observed in the high state at the conjunction orbital phase (0) with the Chandra High Energy Transmission Grating (HETG). Strong and asymmetric absorption lines of highly ionized species were detected, such as Fe XXV, Fe XXIV, Fe XXIII, Si XIV, S XVI, Ne X, etc. In the high state the profile of the absorption lines is composed of an extended red wing and a less extended blue wing. The red wings of higher

ionized species are more extended than those of lower ionized species. The detection of these lines provides a way to probe the properties of the flow around the companion and the black hole in Cyg X-1 during the high state. A broad emission feature around 6.5 keV was significantly detected from the spectra of both the Chandra/HETG and the RXTE/Proportional Counter Array. This feature appears to be symmetric and can be fitted with a Gaussian function rather than the Laor disk line model of the fluorescent Fe K α line from an accretion disk. The implications of these results on the structure of the accretion flow

of Cyg X-1 in the high state are discussed.

18. Title: Does the Iron K α Line of Active Galactic Nuclei Arise from the Cerenkov Line-like Radiation?

Authors: You, J. H.; Liu, D. B.; Chen, W. P.; Chen, L.;
Zhang, S. N.
Journal: The Astrophysical Journal, Volume 599, Issue 1, pp.
164-172.
Publication Date: 12/2003
Origin: UCP
ApJ Keywords: Galaxies: Active, Radiation Mechanisms: Nonthermal,
X-Rays: Galaxies
Abstract Copyright: (c) 2003: The American Astronomical Society
Bibliographic Code: 2003ApJ...599..164Y

Abstract

When thermal relativistic electrons with isotropic distribution of velocities move in a gas region or impinge upon the surface of a cloud that consists of a dense gas or doped dusts, the Cerenkov effect produces peculiar atomic or ionic emission lines, which is known as the Cerenkov line-like radiation. This newly recognized emission mechanism may find wide applications in high-energy astrophysics. In this paper we tentatively adopt this new line emission mechanism to discuss the origin of the iron K α feature of active galactic nuclei (AGNs). The motivation of this research is to attempt a solution to a problem encountered by the 'disk fluorescence line' model, i.e., the lack of temporal response of the observed iron K α line flux to the changes of the X-ray continuum flux. If the Cerenkov line emission is indeed responsible significantly for the iron K α feature, the conventional scenario around the central supermassive black holes of AGNs would need to be modified to accommodate more energetic, more violent, and much denser environments than previously thought.

Conference Presentations

1. Title: A New Method to Use Chandra Data to Resolve the X-Ray Halos Around Point Sources and Its Application to Cygnus X-1
Authors: Yao, Y.; Zhang, S. Nan; Zhang, X. L.; Feng, Y. X.
Journal: American Astronomical Society Meeting 202, #29.18
Publication Date: 05/2003
Origin: AAS
Abstract Copyright: (c) 2003: American Astronomical Society
Bibliographic Code: 2003AAS...202.2918Y

Abstract

The excellent angular resolution, good energy resolution and broad energy band make Chandra ACIS the best instrument for studying the X-ray halos around some galactic X-ray point sources caused by the dust

scattering of X-rays in the interstellar medium, but the direct images of bright sources obtained with ACIS usually suffer from severe pile-up.

Making use of the fact that an isotropic image could be reconstructed from its projection on any direction, we can reconstruct the images of the X-ray halos from the data obtained with the regular HETGS and/or the

CC mode. These data are nearly or totally pile-up free and enable us to take full advantage of the excellent angular resolution of Chandra.

With

the reconstructed high resolution images, we can probe the X-ray halos as close as 1 arcsecond to their associated point sources. Applying this

method to Cygnus X-1 observed with Chandra HETGS in CC mode, we derive an energy dependent radial halo flux distribution and conclude that, for

a 1 arcminute region around the point source: (1) relative to the total intensity, the fractional halo intensity in Cygnus X-1 is about 35% at about 1 keV and drops to about 10% at around 6 keV; (2) about 50% of the

halo photons is within less than 30 arcsecond region; and (3) the spectrum of the point source is distorted by the halo contamination, especially in the soft energy band below 3 keV.

2. Title: The Growth of Central Black Hole and the Ionization Instability of Quasar Disk

Authors: Lu, Ye; Cheng, K. S.; Zhang, S. N.

Journal: American Astronomical Society, HEAD meeting #35, #21.09

Publication Date: 03/2003

Origin: AAS

Abstract Copyright: (c) 2003: American Astronomical Society

Bibliographic Code: 2003HEAD...35.2109L

Abstract

A possible accretion model associated with the ionization instability of

quasar disks is proposed to address the growth of the central black hole

harbored in the host galaxy. The evolution of quasars in cosmic time is assumed to change from a highly active state to a quiescent state triggered by the S-shaped ionization instability of the quasar accretion

disk. For a given external mass transfer rate \dot{M}_{ext} supplied by the quasar host galaxy, ionization instability can modify accretion rate in the disk and separates the accretion flows of the disk

into three different phases, like a S-shape. We suggest that the bright quasars observed today are those quasars with disks in the upper branch of S-shaped instability, and the faint or 'dormant' quasars are simply the system in the lower branch. The middle branch is the transition state which is unstable. We assume the quasar disk evolves according to the advection-dominated inflow-outflow solutions (ADIOS) configuration in the stable lower branch of S-shaped instability, and Eddington

accretion rate is used to constrain the accretion rate in each phase. The mass ratio between black hole and its host galactic bulge is a nature consequence of ADIOS. Our model also demonstrates that a seed BH ($\sim 2 \times 10^6 M_{\text{sun}}$) similar to those found in spiral galaxies today is needed to produce a BH with a final mass ($\sim 2 \times 10^8 M_{\text{sun}}$).

This work was supported by the National Natural Science Foundation of China (NSFC 10273011) and the National 973 Project (NKBRSF G19990754).

3. Title: **Dominant gamma-ray bursts production in the early universe**
Authors: **Zhang, S. N.**; Lin, J. R.; Li, T. P.
Journal: American Astronomical Society, HEAD meeting #35, #16.03
Publication Date: 03/2003
Origin: AAS
Abstract Copyright: (c) 2003: American Astronomical Society
Bibliographic Code: 2003HEAD...35.1603Z

Abstract

It has been known that at least some of the observed gamma-ray bursts (GRBs) are produced at cosmological distances and the GRB production rate may follow the star formation rate. Here we report that the lower and upper distance limits to the GRB production are $z \approx 0.22$ and $z > 8$, respectively, as determined from BATSE's GRB fluence distribution. This result suggests that GRBs are no longer produced presently, and that the actual star formation rate peaks at much higher redshift and thus the "dark ages" of the universe have ended much earlier than believed previously. We have also determined that the GRB opening angles follow an exponential distribution with a mean opening angle of about 0.03 radian.

This study is supported in part by the Special Funds for Major State Basic Research Projects and by the National Natural Science Foundation of China. SNZ also acknowledges supports by NASA's Marshall Space Flight Center and through NASA's Long Term Space Astrophysics Program.

4. Title: **RX J1856.5-3754: a Strange Star with Solid Quark Surface?**
Authors: Zhang, Xiaoling; Xu, Renxin; **Zhang, Shuangnan**
Journal: Young Neutron Stars and their Environment, International Astronomical Union. Symposium no. 218, held 14-17 July, 2003 in Sydney, Australia
Publication Date: 00/2003
Origin: IAU
Bibliographic Code: 2003IAUS..218E.217Z

Abstract

The featureless spectra of isolated "neutron stars" may indicate that

they are actually bare strange stars but a definitive conclusion on the nature of the compact objects cannot be reached until accurate and theoretically calculated spectra of the bare quark surface are known. However due to the complex nonlinearity of quantum chromodynamics it is almost impossible to present a definitive and accurate calculation of the density-dominated quark-gluon plasma from the first principles. Nevertheless it was suggested that cold quark matter with extremely high baryon density could be in a solid state. Within the realms of this possibility we have fitted the 500ks Chandra LETG/HRC data for the brightest isolated neutron star RX J1856.5-3754 with a phenomenological spectral model and found that electric conductivity of quark matter on the stellar surface is about $1.5 \times 10^{16} \text{ s}^{-1}$.

5. Title: **An Accretion Model for the Growth of Black Hole in Quasars**
Authors: Lu, Ye; Cheng, K. S.; Zhang, S. N.
Journal: Quasar Cores and Jets, 25th meeting of the IAU, Joint Discussion 18, 23-24 July 2003, Sydney, Australia
Publication Date: 00/2003
Origin: IAU
Bibliographic Code: 2003IAUJD..18E...4L

Abstract

A possible accretion model associated with the ionization instability of quasar disks is proposed to address the growth of the central black hole harbored in the host galaxy. The evolution of quasars in cosmic time is assumed to change from a highly active state to a quiescent state triggered by the S-shaped ionization instability of the quasar accretion disk. For a given external mass transfer rate ionization instability can modify accretion rate in the disk and separates the accretion flows of the disk into three different phases like a S-shape. We suggest that the bright quasars observed today are those quasars with disks in the upper branch of S-shaped instability and the dormant quasars are the system in the lower branch. The disk is assumed to evolve as ADIOS configuration in the lower branch. The mass ratio between black hole and its host galactic bulge is a nature consequence of ADIOS. Our model also demonstrates that a seed BH ($\sim 2 \times 10^6 M_{\odot}$) similar to those found in spiral galaxies today is needed to produce a BH with a final mass ($\sim 2 \times 10^8 M_{\odot}$).

6. Title: **Dominant gamma-ray bursts production in the early universe**
Authors: Zhang, S. N.; Lin, J. R.; Li, T. P.
Affiliation: AA(THU/UAH/NSSTC/IHEP), AB(THU), AC(THU/IHEP)
Journal: American Astronomical Society Meeting 201, #147.01
Publication Date: 12/2002
Origin: AAS

Abstract Copyright: (c) 2002: American Astronomical Society
Bibliographic Code: 2002AAS...20114701Z

Abstract

It has been known that at least some of the observed gamma-ray bursts (GRBs) are produced at cosmological distances and the GRB production rate may follow the star formation rate. Here we report that the lower and upper distance limits to the GRB production are $z \approx 0.24$ and $z > 10$, respectively. This result suggests that GRBs are no longer produced presently, and that the actual star formation rate peaks at much higher redshift and thus the "dark ages" of the universe have ended much earlier than believed previously.

This study is supported in part by the Special Funds for Major State Basic Research Projects and by the National Natural Science Foundation of China. SNZ also acknowledges supports by NASA's Marshall Space Flight Center and through NASA's Long Term Space Astrophysics Program.

7. Title: Spectroscopy of Cyg X-1 the High State with HETG/Chandra
Authors: Feng, Y. X.; Tennant, A.; Zhang, S. N.
Journal: American Astronomical Society, 201st AAS Meeting, #57.02; Bulletin of the American Astronomical Society, Vol. 34, p.1206
Publication Date: 12/2002
Origin: AAS
Abstract Copyright: (c) 2002: American Astronomical Society
Bibliographic Code: 2002AAS...201.5702F

Abstract

Cyg X-1 was observed in the high state around orbital phase 0 with HETG/Chandra. Significant absorption lines of highly ionized species were detected, such as Fe XXV, Fe XXIV, Fe XXIII, S XIV, S XVI, Ne X, etc. The observed absorption lines are found to be blue-shifted ($z \sim -0.002$) from those observed in the low and transition states. In the high state each absorption line was composed of a blue-shifted absorption line and a un-shifted absorption line which similar to that observed in the low state. The broad line feature of Fe K_α at 6.4 keV was detected with a significance of $\Delta\chi^2 \sim 40$, although precise measurements are hindered by uncertainties in the calibration. The implications of these results on the configuration of the accretion flow of Cyg X-1 in the high state are discussed.

8. Title: Relativistic Effects Around Black Holes: Smearing of Absorption Edges
Authors: Zhang, X. L.; Feng, Y. X.; Zhang, S. N.; Yao, Y.
Journal: American Astronomical Society, 201st AAS Meeting,

#15.05; Bulletin of the American Astronomical Society, Vol. 34, p.1123

Publication Date: 12/2002

Origin: AAS

Abstract Copyright: (c) 2002: American Astronomical Society

Bibliographic Code: 2002AAS...201.1505Z

Abstract

Broad iron absorption structures have been observed in the X-ray spectra of both AGNs and black hole X-ray binaries (BHXBs). A correctly modeled absorption structure can reveal the physical condition of the source, help to determine the continuum spectra and thus help to estimate other spectral features more accurately. The absorption structures are usually thought to be caused by the reflection of X-rays by the accretion disks around the central black holes, and the broadening can be attributed to the ionization states of the disk and relativistic effects. Both AGNs and BHXBs harbor black holes, and in some systems the accretion disks can extend to very close to the black holes. Like the broadening effect on emission lines, the relativistic broadening on absorption edges can be very significant for these systems, especially when the central black hole is rotating rapidly. In general, a faster spin black hole and a higher inclination angle will distort the structure more seriously. In this work we will study in detail how the spin of the central black hole and the inclination angle of the disk will affect the properties of the absorption edges, the central energy, the profile and the strength etc.. The model will be compared to Chandra/XMM observations.

9. Title: Using Monte-Carlo Simulations to Study the Disk Structure in Cygnus X-1
Authors: Yao, Y.; Zhang, S. N.; Zhang, X. L.; Feng, Y. X.
Journal: American Astronomical Society, 201st AAS Meeting, #15.02; Bulletin of the American Astronomical Society, Vol. 34, p.1122
Publication Date: 12/2002
Origin: AAS
Abstract Copyright: (c) 2002: American Astronomical Society
Bibliographic Code: 2002AAS...201.1502Y

Abstract

As the first dynamically determined black hole X-ray binary system, Cygnus X-1 has been studied extensively. However, its broad-band spectra in hard state with BeppoSAX is still not well understood. Besides the soft excess described by the multi-color disk model (MCD), the power-law component and a broad excess feature above 10 keV (disk reflection component), there is also an additional soft component around 1 keV, whose origin is not known currently. Here we propose that the additional

soft component is due to the thermal Comptonization process between the soft disk photon and the warm plasma cloud just above the disk, i.e., a warm layer. We use Monte-Carlo technique to simulate this Compton scattering process and build several table models based on our simulation results. With these table models, we study the disk structure

in Cygnus X-1. According to the fitting results with our table models, the electron energy distribution in the corona follows the Maxwellian form and if the warm layer we proposed here is the commonly observed outflow in x-ray binary system, the outflow velocity is about 0.01-0.02 c in Cygnus X-1.

10. Title: **How do the relativistic effects affect the appearance of a clothed black hole?**
Authors: Zhang, Xiaoling; Zhang, S. N.; Feng, Yuxin; Yao, Yangsen
Journal: American Physical Society, April Meeting, Jointly Sponsored with the High Energy Astrophysics
Division (HEAD) of the American Astronomical Society April
20 - 23, 2002 Albuquerque Convention Center
Albuquerque, New Mexico Meeting ID: APR02, abstract #N17.085
Publication Date: 04/2002
Origin: APS
Bibliographic Code: 2002APS..APRN17085Z

Abstract

For an accretion disk around a black hole, the strong relativistic effects affect every aspect of the radiation from the disk, including the spectrum, the light-curve, and the image. If the disk is in high inclination angle (nearly edge-on), the image will be greatly distorted; the farther side of the disk will appear to bend toward the observer, photons from the other side of the disk can reach the observer (if they are not blocked by the disk) to form a ghost image. This work differs mainly from previous work by taking into account the temperature distribution of a standard thin disk model and investigating the expected images from different viewing angles and in different energy bands. The edge-blocking effect is also considered. Direct images of black hole systems may be obtained with future X-ray missions like MAXIM pathfinder.

11. Title: **Inclination Angles of Black Hole X-ray Binaries Manifest Strong Gravity around Black Holes**
Authors: Zhang, S. N.; Zhang, Xiaoling; Yao, Yangsen
Journal: American Physical Society, April Meeting, Jointly

Division
20

Sponsored with the High Energy Astrophysics
(HEAD) of the American Astronomical Society April
- 23, 2002 Albuquerque Convention Center
Albuquerque, New Mexico Meeting ID: APR02, abstract
#N17.083

Publication Date: 04/2002
Origin: APS
Bibliographic Code: 2002APS..APRN17083Z

Abstract

System inclination angles have been determined for about 15 X-ray binaries, in which stellar mass black holes are considered to exist. These inclination angles range between 25 degrees and 80 degrees, but peaked between 60-70 degrees. This peak is not explained in the frame work of Newtonian gravity. However, this peak is reproduced naturally if we model the observed X-ray radiations as being produced in the accretion disks very close to the black hole horizons, where the extremely strong general and special relativistic effects, caused by the extremely strong gravity near the black hole horizons, modify the local radiation significantly as the X-rays propagate to the remote observer. Therefore the peak of the inclination angle distribution provides evidence for strong gravity around stellar mass black holes.

12. Title: **Chandra Observations of Cygnus X-1 at Different Spectral States and Different Orbital Phases**

Authors: Feng, Yuxin; Zhang, Shuang Nan; Cui, Wei; Schulz, N. S.

Journal: American Physical Society, April Meeting, Jointly Sponsored with the High Energy Astrophysics

Division
20

(HEAD) of the American Astronomical Society April
- 23, 2002 Albuquerque Convention Center
Albuquerque, New Mexico Meeting ID: APR02, abstract
#N17.081

Publication Date: 04/2002
Origin: APS
Bibliographic Code: 2002APS..APRN17081F

Abstract

Cygnus X-1 has been observed in different spectral states and at different orbit phases with the Chandra High Energy Transmission Grating Spectrometer. The observed absorption line and edge features are different in these observations. These differences may be caused by the variations of the column density at different orbit phases in a photoionized-wind accretion system. The variations of the absorption features observed in different states may also provide information

about
changes in the configuration of the corona and accretion disk around
the
black hole. We present results of our data analysis and discuss the
physical implications of these results.

13. Title: **Studying the warm layer and the hardening factor in
Cygnus x-1**
Authors: Yao, Yangsen; **Zhang, Shuangnan**; Zhang, Xiaoling;
Feng, Yuxin
Journal: American Physical Society, April Meeting, Jointly
Sponsored with the High Energy Astrophysics
Division (HEAD) of the American Astronomical Society April
20 - 23, 2002 Albuquerque Convention Center
Albuquerque, New Mexico Meeting ID: APR02, abstract
#N17.080
Publication Date: 04/2002
Origin: APS
Bibliographic Code: 2002APS..APRN17080Y

Abstract

As the first dynamically determined black hole X-ray binary system,
Cygnus x-1 has been studied extensively. However, its broadband
spectrum
observed with BeppoSax is still not well understood. Besides the soft
excess described by the multi-color disk model (MCD), the power-law
hard
component and a broad excess feature above 10 keV (a disk reflection
component), there is also an additional soft component around 1 keV,
whose origin is not known currently. Here we propose that the
additional
soft component is due to the thermal Comptonization between the soft
disk photons and a warm plasma cloud just above the disk, i.e., a warm
layer. We use the Monte-Carlo technique to simulate this Compton
scattering process and build a table model based on our simulation
results. With this table model, we study the disk structure and
estimate
the hardening factor to the MCD component in Cygnus X-1.

14. Title: **The BATSE Earth Occultation Catalog of Low
Energy
Gamma-Ray Sources**
Authors: Harmon, B. A.; Wilson-Hodge, C. A.; Fishman, G. J.;
Paciesas, W. S.; **Zhang, S. N.**; Finger, M. H.;
Connaughton, V.; Koshut, T. M.; Henze, W.;

Journal: McCollough, M. L.; Sahi, M.; Peterson, B.;
Grindlay, J.; Barret, D.; Shrader, C. R.
American Physical Society, April Meeting, Jointly
Sponsored with the High Energy Astrophysics
Division
(HEAD) of the American Astronomical Society April
20
- 23, 2002 Albuquerque Convention Center
Albuquerque, New Mexico Meeting ID: APR02, abstract
#B17.044
Publication Date: 04/2002
Origin: APS
Bibliographic Code: 2002APS..APRB17044H

Abstract

The Burst and Transient Source Experiment (BATSE), aboard the Compton Gamma Ray Observatory (CGRO), provided a record of the hard X-ray/low energy gamma ray sky between April 1991 and June 2000. During that time, a catalog of known sources was derived from existing catalogs such as HEAO A-4 (Levine et al. 1984), as well as new transient sources discovered with BATSE and other X-ray monitors operating in the CGRO era. The Earth Occultation Technique (Harmon et al. 2001, astro-ph/0109069) was used to monitor a combination of these sources, mostly galactic, totaling to about 175 objects. The catalog will present the global properties of these sources and their probability of detection (> 10 mCrab, 20-100 keV) with BATSE. Systematic errors due to unknown sources or background components are included. cursory analyses to search for new transients (35-80 mCrab in the 20-100 keV band) and super-orbital periods in known binary sources are also presented. Whole mission light curves and associated data production/analysis tools are being delivered to the HEASARC for public use.

15. Title: **The BATSE Earth Occultation Catalog of Low Energy Gamma-Ray Sources**
Authors: Harmon, B. A.; Wilson-Hodge, C. A.; Fishman, G. J.;
Paciesas, W. S.; **Zhang, S. N.**; Finger, M. H.;
Connaughton, V.; Koshut, T. M.; Henze, W.;
McCollough, M. L.; Sahi, M.; Peterson, B.;
Grindlay, J.; Barret, D.; Shrader, C. R.
Journal: American Astronomical Society, 199th AAS Meeting,
#130.07; Bulletin of the American Astronomical
Society, Vol. 33, p.1496
Publication Date: 12/2001
Origin: AAS
Abstract Copyright: (c) 2001: American Astronomical Society
Bibliographic Code: 2001AAS...19913007H

Abstract

The Burst and Transient Source Experiment (BATSE), aboard the Compton

Gamma Ray Observatory (CGRO), provided a record of the hard X-ray/low energy gamma ray sky between April 1991 and June 2000. During that time, a catalog of known sources was derived from existing catalogs such as HEAO A-4 (Levine et al. 1984), as well as new transient sources discovered with BATSE and other X-ray monitors operating in the CGRO era. The Earth Occultation Technique (Harmon et al. 2001, astro-ph/0109069) was used to monitor a combination of these sources, mostly galactic, totaling about 175 objects. The catalog will present the global properties of these sources and their probability of detection (>10 mCrab, 20-100 keV) with BATSE. Systematic errors due to unknown sources or background components are included. cursory analyses to search for new transients (35-80 mCrab in the 20-100 keV band) and super-orbital periods in known binary sources are also presented. Whole mission light curves and associated data production/analysis tools are being delivered to the HEASARC for public use.

16. Title: Studying the Accretion Disks in Black Hole X-ray Binaries with Monte-Carlo Simulations
Authors: Yao, Y.; Zhang, S. N.; Zhang, X.
Journal: Gamma 2001: Gamma-Ray Astrophysics, held 4-6 April, 2001 in Baltimore, MD. Edited by Steven Ritz, Neil Gehrels, and Chris R. Shrader. Also AIP Conference Proceedings, Vol. 587. Melville, NY: American Institute of Physics, 2001., p.106
Publication Date: 00/2001
Origin: ADS
Bibliographic Code: 2001AIPC..587..106Y

Abstract

Not Available

17. Title: Relativistic Effects on X-ray Emission from Accretion Disks around Black Holes
Authors: Zhang, X.; Zhang, S. N.; Yao, Y.
Journal: Gamma 2001: Gamma-Ray Astrophysics, held 4-6 April, 2001 in Baltimore, MD. Edited by Steven Ritz, Neil Gehrels, and Chris R. Shrader. Also AIP Conference Proceedings, Vol. 587. Melville, NY: American Institute of Physics, 2001., p.101
Publication Date: 00/2001
Origin: ADS
Bibliographic Code: 2001AIPC..587..101Z

Abstract

Not Available

18. Title: **The Temporal and Spectral Properties of Cyg X-1 during a Large X-ray Flare**
Authors: Feng, Y. X.; Cui, W.; Zhang, S. N.
Journal: Gamma 2001: Gamma-Ray Astrophysics, held 4-6 April, 2001 in Baltimore, MD. Edited by Steven Ritz, Neil Gehrels, and Chris R. Shrader. Also AIP Conference Proceedings, Vol. 587. Melville, NY: American Institute of Physics, 2001., p.76
Publication Date: 00/2001
Origin: ADS
Bibliographic Code: 2001AIPC..587...76F

Abstract

Not Available

19. Title: **Results of a Deep Chandra Observation of the Crab Nebula and Pulsar**
Authors: Weisskopf, M. C.; Becker, W.; Elsner, R.; Kahn, S.; Kolodziejczak, J.; Murray, S.; O'Dell, S.; Paerels, F.; Shibazaki, N.; Swartz, D.; Tennant, A.; Truemper, J.; Zhang, S. N.
Journal: American Astronomical Society, HEAD Meeting #32, #36.04; Bulletin of the American Astronomical Society, Vol. 32, p.1248
Publication Date: 10/2000
Origin: AAS
Abstract Copyright: (c) 2000: American Astronomical Society
Bibliographic Code: 2000HEAD...32.3604W

Abstract

The Crab Nebula and pulsar were observed for a total of 150 ksec with the LETG/HRC-S combination aboard the Chandra X-Ray Observatory in 2000, January. One of the principal aims of the experiment was to study the emission of from the pulsar as a function of pulse phase. Neutron stars are believed to be formed with core temperatures of $T_{\text{c}} \sim 10^{11}$ K. As the pulsar is the youngest known neutron star with an age of only 940 yrs, it should be possible to observe thermal emission from the hot stellar surface which in turn constrains equations of state. The pulsar, on the other hand, is a powerful non-thermal emitter, powering an X-ray bright synchrotron nebula which, in Einstein and ROSAT observations, overshadowed the fainter thermal surface emission. Making use of the high angular resolution provided by Chandra we were able to detect X-rays from the Crab-pulsar at all pulse phases. We discuss whether this detection is indeed of thermal emission or of a faint synchrotron component of the pulsed emission from the magnetosphere. We further report on dynamical effects observed in the pulsar-wind outflow and the analysis of the LETG spectral data, especially near the oxygen edge. The results of the spectral analysis has interesting implications for the composition of the interstellar medium.

**20. Title: X-ray spectral variations of X-ray nova XTE
J1550-564 during the rising phase of the 1998
outburst**
Authors: Wu, Xuebing; Zhang, S. N.; Yao, Yangsen; Su, Xuejun;
Cui, Wei; Chen, Wan
Journal: Stellar Astrophysics, Proceedings of the Pacific
Rim
Conference held in Hong Kong, 1999. Edited by L. S.
Cheng, H. F. Chau, K. L. Chan, and K. C. Leung,
published by Kluwer Academic Publishers, The
Netherlands, 2000., p.267
Publication Date: 00/2000
Origin: ADS
Bibliographic Code: 2000stas.conf..267W

Abstract

Not Available

**21. Title: Does the inner disk boundary of a black hole X-ray
binary move during an outburst?**
Authors: Zhang, S. N.; Cui, W.; Chen, W.; Harmon, B. A.;
Robinson, C. R.; Sun, X.; Yao, Y.; Zhang, X.
Journal: Rossi2000: Astrophysics with the Rossi X-ray Timing
Explorer. March 22-24, 2000 at NASA's Goddard Space
Flight Center, Greenbelt, MD USA, p.E112
Publication Date: 00/2000
Origin: AUTHOR
Bibliographic Code: 2000arxt.confE.112Z

Abstract

Comptonization in the corona of an X-ray binary may reduce
significantly
the flux in the observed soft component of its X-ray spectrum.
Therefore
the apparent inner disk radius inferred from the observed soft
component
may change in accordance to the fraction of the disk emission scattered
into the hard component. We have developed a simple numerical model for
carrying out the radiative transfer correction, in order to determine
the original disk emission before the Comptonization in the hot corona.
Applying this model to the extensive monitoring data of several black
hole X-ray binaries with RXTE, we have found that most of the
previously
reported inner disk radius variations may be explained as due to this
radiative transfer effect in the corona. We thus conclude that there is
currently no evidence for significant inner disk boundary movement
during the outbursts of these black hole X-ray binaries we have studied
with the RXTE data: GROJ1655-40, XTEJ1550-564, XTEJ1748-288 and
XTEJ2012+381.

22. Title: RXTE and BATSE Observations of the Recent Outbursts of 2S 1417-624
Authors: Finger, M. H.; Heindl, W. A.; Zhang, S. N.
Journal: Rossi2000: Astrophysics with the Rossi X-ray Timing Explorer. March 22-24, 2000 at NASA's Goddard Space Flight Center, Greenbelt, MD USA, p.E48
Publication Date: 00/2000
Origin: AUTHOR
Bibliographic Code: 2000arxt.confE..48F

Abstract

2S 1417-624 is a 57 mHz transient Be/X-ray pulsar system first discovered by SAS 3 in 1978. After the discovery outburst it was not seen again until 1994 when BATSE observed an outburst that peaked at 40 mCrab (pulsed flux, 20-50 keV) and lasted 110 days, followed by a series of 5 shorter, 10-15 mCrab outbursts occurring every 42 days. Pulse timing analysis showed that these smaller outbursts began a few days after periastron passage of the system's eccentric, 42 day period orbit. Renewed activity from the source was detected by BATSE beginning in 1999 November. BATSE monitoring shows a 10 mCrab peak flux outburst lasting 10 days, followed in the next orbit by a 30 mCrab peak flux outburst, which to date has lasted 56 days. Regular monitoring with RXTE began during the 1999 November outburst and has continued into the current outburst. The data provides good coverage of the low flux state between BATSE detections, which includes the periastron passage. Pulses are detected through this interval, showing that the source did not enter the propeller regime. The PCA monitoring from the lowest flux level, which occurs shortly before periastron, until the peak of the current outburst, show a continuous evolution of the pulse profile. These profiles contain a narrow notch feature which allow us to present a phase aligned history of this pulse evolution. We present a timing analysis of the PCA and BATSE observations that provide corrections to the binary orbit, and measurements of the torque during the observations. From the observed torque and flux we show that disc accretion is occurring in the current outburst, most probably was also occurring in the smaller outburst.

23. Title: The Earth Occultation Technique with the Burst and Transient Source Experiment
Authors: Wilson, C. A.; Harmon, B. A.; McCollough, M. L.; Fishman, G. J.; Zhang, S. N.; Paciesas, W. S.
Journal: Astronomical Data Analysis Software and Systems IX, ASP Conference Proceedings, Vol. 216, edited by Nadine Manset, Christian Veillet, and Dennis Crabtree. Astronomical Society of the Pacific, ISBN 1-58381-047-1, 2000., p.587
Publication Date: 00/2000
Origin: AUTHOR; ADS

Abstract

The Burst and Transient Source Experiment (BATSE) on the Compton Gamma Ray Observatory (CGRO) is successfully being used as an all-sky hard X-ray monitor. The experiment consists of a set of eight uncollimated detectors sensitive to photons in the 20 keV to 2 MeV range. Since CGRO orbits the Earth at an altitude of about 450 km, about 33% of the sky, as viewed with BATSE, is covered by the Earth at any given time. The entire sky is subject to Earth occultation for some portion of CGRO's 52

day precession period. When a source sets below or rises above the Earth's limb, atmospheric attenuation produces step-like features in the

BATSE data. The observed change in count rate in several energy bands provides a measurement of the source intensity and spectrum without sophisticated background models. These occultation features are used to locate and monitor astrophysical sources with BATSE when the source signal can be separated from the detector background. Examples of step searches, spectra, light curves, and transform imaging are presented.

24. Title: The Timing Evolution of 4U 1630-47 During its 1988

Outburst.

Authors: Dieters, S. W.; Belloni, T.; Kuulkers, E.; Woods, P.; van Paradijs, J.; Cui, W.; Swank, J. H.; **Zhang, S.-N.**

Journal: American Astronomical Society, 195th AAS Meeting, #134.05; Bulletin of the American Astronomical Society, Vol. 32, p.882

Publication Date: 12/1999

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Abstract Copyright: (c) 1999: American Astronomical Society

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Abstract

We report on the timing analysis of Rosssi X-ray Timing Explorer (RXTE) observations of 4U 1630-47 made during its 1998 outburst. In addition we

use two BeepoSAX observation on the late decline. 4U1630-47 showed seven

distinct types of timing behaviour, most of which show differences with the canonical black hole spectral/timing states. In marked contrast to previous outbursts we find quasi periodic oscillation (QPO) signals during nearly all stages of the outburst. In addition to 2 to 13 Hz QPO slow 0.01Hz QPO are observed. These slow QPO can dominate the light curve as quasi-regular 5 sec, 9--16% deep dips. During these dips we track the behaviour of two QPO's; one remaining constant near 13.5 Hz and the other varying between 7 and 4 Hz. The evolution of the timing and the concurrent spectral changes are mapped using a combination harness-intensity and colour-colour diagrams.

25. Title: Evolution of the Iron K-alpha Emission Line in the Black Hole Candidate GX339-4 During an Outburst Decay Phase

Authors: Feng, Y.; Zhang, S.-N.; Chen, W.; Cui, Wei

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Journal: American Astronomical Society, 195th AAS Meeting, #126.05; Bulletin of the American Astronomical Society, Vol. 31, p.1556

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Abstract

The evolution of the iron K-alpha line emission feature was found from the black hole candidate GX339-4 when its X-ray flux (2 to 10 keV) decreased significantly from 5.0×10^{-9} erg cm⁻² s⁻¹ to 1.0×10^{-11} erg cm⁻² s⁻¹. With RXTE observations, a broad line emission feature around 7 keV was detected in its quiescent and low flux state; while in the high flux state, an emission line feature around 6.4 keV was detected. A similar 6.4 keV line feature was also detected with previous ASCA observations in a high flux state. We consider that the evolution could be the evidence of the variations in the geometric structure and the physical properties of the accretion flow when the accretion rate changed. This is because that the 7 keV line feature can be produced by the radiative recombination cascade, collisional excitation, and fluorescence of Fe XXVI and Fe XXV, which can exist in a very high temperature plasma; while the 6.4 keV line feature can be produced by fluorescent K-alpha line emission of neutral iron atoms in the cold accretion disk.

26. Title: Discovery of a three-layered atmospheric structure in accretion disks around stellar-mass black holes

Authors: Zhang, S. N.; Zhang, Xiaoling; Sun, Xuejun; Yao, Yangsen; Cui, Wei; Chen, Wan; Wu, Xuebing; Xu, Haiguang

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Abstract

We have carried out systematic modeling of the X-ray spectra of the Galactic superluminal jet sources GRS 1915+105 and GRO J1655-40, using our newly developed spectral fitting methods. Our results reveal, for the first time, a three-layered structure of the atmosphere in the inner region of the accretion disks. Above the commonly known, cold and

optically thick disk of a blackbody temperature 0.2-0.5 keV, there is a layer of warm gas with a temperature of 1.0-1.5 keV and an optical depth

of around 10. Compton scattering of the underlying disk blackbody photons produces the soft X-ray component we commonly observe. Under certain conditions, there is also a much hotter, optically thin corona above the warm layer, characterized by a temperature of 100 keV or higher and an optical depth of unity or less. The corona produces the hard X-ray component typically seen in these sources. We emphasize that the existence of the warm layer seems to be independent of the presence of the hot corona and, therefore, it is not due to irradiation of the disk by hard X-rays from the corona. Our results suggest a striking structural similarity between the accretion disks and the solar atmosphere, which may provide a new stimulus to study the common underlying physical processes operating in these vastly different systems. We also report the first unambiguous detection of an emission line around 6.4 keV in GRO J1655-40, which may allow further constraining of the accretion disk structure. We acknowledge NASA GSFC and MSFC for partial financial support.

